The Accuracy of Gastric Insufflation in Testing for Gastroesophageal Perforations during Laparoscopic Nissen Fundoplication

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ABSTRACT

Background: Laparoscopic Nissen fundoplication is an effective technique for the symptomatic relief of the manifestations of gastroesophageal reflux disorder but is associated with a 0.8-1% rate of gastroesophageal perforation. Early detection and repair of these injuries is critical to patient outcome, but occult injuries occur and may be missed. Gastric insufflation technique evaluates the integrity of the gastroesophageal wall after laparoscopic Nissen fundoplication. Gastric insufflation technique involves occlusion of the proximal stomach with a non-crushing bowel clamp while insufflating the submerged gastroesophageal junction. We conducted an animal study to assess the utility of gastric insufflation technique.

Methods: Five pigs (mean weight, 40.4 kg) underwent testing of laparoscopic gastric insufflation technique. In four animals, laparoscopic Nissen fundoplication was performed and then gastroesophageal junction injuries were created (3-5 mm distraction-type wall injuries). Non-crushing bowel clamps provided occlusion of the pylorus and then the proximal stomach during gastroesophageal insufflation. The gastroesophageal junction was then submerged. In the fifth animal, gastric insufflation technique was repeated while calibrated injuries were created to determine the smallest detectable injury. An injury was considered detectable if rising air bubbles were noted from the submerged gastroesophageal structures. Maximal luminal pressures needed to detect injuries were recorded with an in-line manometer.

Results: In all animals, 5-7 mm injuries of the gastroesophageal junction were easily detected using gastric insufflation technique when the proximal stomach was occluded. When the pylorus alone was occluded, detection of gastroesophageal injuries was inconsistent. Small injuries (<3 mm) of the esophagus were difficult to visualize with pyloric occlusion alone but were consistently detectable with proximal stomach occlusion at pressures less than 20 mm Hg. When the pylorus alone was occluded, the smallest detectable stomach perforation was a 16-gauge needle puncture while applying maximal gastric pressure (40-60 mm Hg) and a 2.5 mm linear injury when generating lower pressures (20 mm Hg).

Conclusion: Proximal stomach occlusion and insufflation appears to effectively detect esophageal injuries of likely clinical importance (>2.5 mm). Pyloric occlusion and insufflation reliably evaluates the anterior stomach for injury. Gastric insufflation technique is a useful method for detecting gastroesophageal injury after laparoscopic Nissen fundoplication.

Key Words: Laparoscopy, Nissen fundoplication, Gastroesophageal injury, detection.

INTRODUCTION

Laparoscopic Nissen fundoplication (LNF) is an effective technique for the symptomatic relief of the manifestations of gastroesophageal reflux disorder (GERD). In large reviews, laparoscopic Nissen fundoplication has been performed with limited morbidity and mortality.[1] The most common complications include early (but usually transient) dysphagia (20%), pneumothorax (2%) and esophageal or gastric perforation (1.1%).[1] The morbidity associated with this procedure is particularly relevant because although GERD is associated with significant patient complaints, it is usually not life threatening. For that reason, the acceptance of a surgical procedure for its resolution is critically dependent on a low rate of complications. While postoperative dysphagia is the most common of these complications, it is usually self-limited. Conversely, intraoperative perforation of either the stomach or the esophagus is much less common, but its consequences are quite significant.

When detected at the time of the procedure, gastroesophageal (GE) perforation is associated with limited morbidity and is unlikely to result in patient death.[2]

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However, delay in the diagnosis of GE injuries results in peritonitis, sepsis and a high mortality rate. In one series of patients undergoing laparoscopic Nissen fundoplication, delayed detection of GE injury resulted in 17% mortality.[2] Because of the dramatic differences in outcome based on early identification of GE injuries, we have attempted to develop a technique for intraoperative detection of GE injuries.

The standard technique of laparoscopic Nissen fundoplication does not include an effective survey for GE injuries. Many GE injuries occur during passage of the bougie dilator[2,3] and are obvious at the time of injury. However, others are the result of improper dissection of the posterior GE window or from graspers placed on the stomach. Dissector and grasper injuries may easily go undetected because of their innocuous appearance adjacent to a surgical dissection. Although some practitioners rely on routine postoperative radiologic studies to evaluate for injury, this technique does not allow for repair during the initial operative setting. Instillation of methylene blue into the stomach via the nasogastric tube has been used by others to detect injury.[3] Infusions of methylene blue into the stomach require large volumes to conclusively exclude injury and put the patient at risk for aspiration. As well, volume infusions will only effectively detect injuries in the dependent wall unless the GE volume is completely filled. Routine endoscopy at the completion of the procedure may not reliably identify smaller defects.

We developed a gastric insufflation technique (GIT) for this purpose and have applied it in patients undergoing laparoscopic Nissen fundoplication. Gastric insufflation technique involves occlusion of the stomach with a non-crushing bowel clamp while insufflating the submerged stomach and esophagus with air. Gastric insufflation technique appears to effectively evaluate the integrity of the GE wall; however, we have detected no injuries while using the technique. This animal study was designed to confirm our clinical experience and to assess the utility of GIT.

METHODS

Five, female Yorkshire pigs (mean weight, 40.4 kg) were anesthetized following a 24-hour fast. After routine establishment of pneumoperitoneum (15 mm Hg), laparoscopic mobilization of the stomach and GE junction was completed through five 11 mm ports. To complete the procedure, all short gastric vessels were routinely divided using the Ultracision® harmonic scalpel (Ethicon Endo-Surgery, Cincinnati, Ohio). In four animals, a variety of GE junction injuries were intentionally created using endoscopic dissectors and shears. Injuries were created by dissecting into the lumen of the esophagus to the point of nasogastric tube (NGT) visualization (3-5 mm distraction-type wall injuries). After creating injuries in the distal esophagus and GE junction, the pylorus was occluded using an endoscopic bowel clamp (Ethicon Endo-Surgery, Cincinnati, Ohio). The stomach and the esophagus were evaluated for injuries using the gastric insufflation technique.

Gastric Insufflation Technique (GIT)

Gastric insufflation technique was performed by insufflating the submerged stomach and esophagus with room air using a modified 18F nasogastric tube. The Salem® sump nasogastric tube (NGT) was modified by attaching a pressure "ball" with a one-way valve to the drainage port. A manometer was attached to the blue port to determine intragastric pressure during insufflation. Intragastric pressures were reported uncorrected for intra-abdominal pressure of 15 mm Hg. While inflating the stomach during pyloric occlusion, the luminal integrity of the stomach and esophagus were assessed by carefully checking for air leakage. The NGT was then pulled back to the esophagus, and the proximal stomach was occluded during insufflation. The esophagus was then closely examined for air leakage. In all cases, an injury was considered detectable if rising air bubbles were noted from the submerged GE junction or stomach. Maximal luminal pressures needed to detect injuries were recorded.

Laparoscopic Nissen fundoplication was completed in two of five animals, after which GIT was repeated with pyloric occlusion. In the fifth animal, the stomach and GE junction were mobilized, and the pylorus was occluded laparoscopically while calibrated injuries were created on the anterior stomach wall and esophagus. Injuries were created using 23, 20, 18 and 16-gauge needles along with a #11 scalpel. To generate maximal gastric pressures, these maneuvers were repeated with the abdomen open. The animals were euthanized at the termination of the procedure. All animals were cared for in accordance with National Institute of Health (NIH) protocol.

RESULTS

In four of four animals, when the proximal stomach was occluded, 5-7 mm injuries of the posterolateral esophagus at the GE junction were easily detected with GIT. Gastric insufflation technique with proximal occlusion required minimal insufflation (mean <20 mm Hg), and, for every pump of the pressure ball, air bubbles were detected without manipulation of the stomach. When the pylorus alone was occluded, a higher pressure (mean 27 mm Hg) was required to sufficiently distend the stomach and reveal the injury. In the neutral position, pyloric occlusion alone did not consistently detect injuries. However, lateral retraction of the stomach allowed detection of GE injuries. Small injuries (<3 mm) of the esophagus were difficult to visualize with pyloric occlusion alone but were consistently detectable with proximal stomach occlusion at pressures less than 20 mm Hg. Completion of Nissen fundoplication (two animals) did not impair detectability of GE junction dissection injuries.

When the pylorus alone was occluded, the smallest detectable stomach perforation was a 16-gauge needle puncture at maximal gastric pressure (40-60 mm Hg). These pressures were generated in the open abdomen with manual manipulation of the stomach after maximal insufflation. Using laparoscopic techniques, GIT was unable to generate gastric pressures greater than 30 mm Hg. At lower pressures (20-30 mm Hg) linear, gastric injuries 2.5 mm in length were reliably detected with pyloric occlusion. With proximal stomach occlusion, 2.5 mm injuries of the GE junction and esophagus were easily detected with gastric pressure of 30 mm Hg.

DISCUSSION

Despite the growing acceptance of laparoscopic Nissen fundoplication for the treatment of GERD, persistent questions remain regarding associated surgical morbidity. Although much discussion has focused on dysphagia after LNF, this complication is most often self-limited and has minimal long-term implications. Persistent dysphagia requires endoscopic dilatation in only 3.5% of cases and operative revision in 0.9%.[1] While it occurs much less commonly, gastroesophageal injury during laparoscopic foregut surgery has greater implication for both patient and surgeon.

The likelihood of injury is directly related to surgical experience. Yet, because there is a relatively small number of patients who require LNF, many surgeons have limited experience with this advanced technique. This is unfortunate because the procedure clearly represents a higher level of laparoscopic complexity than cholecystectomy and may require a longer learning curve before the risks are appropriately minimized.[4] Schauer et al[2] found that the majority of injuries occurred during the surgeon's first ten cases. In this review,[2] ten injuries occurred within the first ten procedures of 14 different surgeons. Two GE injuries occurred after the surgeon had performed more than 20 procedures. Conversely, when the results of only experienced surgeons are evaluated only sporadic reports of injury are noted.[4,5]

Recent reviews[2,3] have retrospectively evaluated the incidence and mechanism of GE injuries after LNF. In a multicenter report of 2453 patients undergoing LNF, 1.1% had either esophageal or gastric perforation.[1] Lowham et al[3] reported 13 esophageal or gastric injuries out of a total of 1620 laparoscopic foregut operations (0.8%). This rate represents a higher incidence of GE injuries than that found with the dilatation of benign esophageal strictures (0.1%). Dilatation of esophageal strictures has been commonly considered the procedure at highest risk for perforation of the esophagus. The rate of injury commonly reported (1%) is clearly higher than that found with "open" fundoplication.

The review by Lowham et al[3] focused on injuries from intraesophageal mechanisms. In their series, 11 occurred during bougie insertion and 2 during NGT placement. Five injuries were repaired using an "open" abdominal procedure, and in two patients thoracotomy was performed in a delayed setting. To avoid such injuries, the authors emphasize the importance of caudal and anterior retraction of the stomach during passage of the bougie. Furthermore, the crura should not be reapproximated prior to bougie placement because this displaces the esophagus anteriorly while the stomach lies posterior. This can easily result in anterior GE junction injury. Six of 13 perforations were related to this mechanism. Other important considerations include avoiding rapid insertion of the bougie, maintaining appropriate communication with the team member inserting the bougie, using only experienced personnel for this part of the procedure and not passing dilators in the presence of esophageal diverticula.[3]

Schauer et al[2] evaluated GE injuries after LNF and focused on techniques of operative dissection. Among

17 gastric and esophageal perforations after LNF, three mechanisms accounted for all injuries. Ten injuries were from improper retroesophageal dissection (nine resulted from dissection in an improper operative plane). One occurred as a result of an inappropriately limited retroesophageal window causing a tear of the fundus during fundoplication. Five other injuries occurred during passage of the bougie (n=4) or NGT (n=1). Two injuries occurred after suture pull through of "full-thickness" stomach sutures. The estimated size of injuries was 0.5-2 cm (mean 1.1 cm). Contributing findings among patients with injuries included obesity, hiatal hernia, excessive fatty tissue in the periesophageal area and blood staining of the operative field.[2]

Of these injuries,[2] most (n=11) were recognized at the time of the surgery. Four injuries were repaired through the laparoscope, five through laparotomy, and one through thoracotomy. Six cases (35%) were identified after surgery. Presenting findings in this group included persistent abdominal pain, peritonitis and respiratory distress. On average, these injuries were identified 1-6 days after surgery with the principal presenting sign of increased abdominal pain in 67%. At least one patient had a documented GE injury despite a reassuring barium study of the GE junction.

Outcomes after injury detection and repair vary significantly based on the time of discovery. Those injuries identified at the time of perforation were associated with a 0% mortality rate, no postoperative leaks and mean hospital stay of 4.5 days. Of those six patients with delayed discovery of injuries, one died (17%), abscess was noted in two, and pleural effusions, fistula, or vagus nerve injury were also noted. In the delayed diagnosis group, the mean hospital stay was 14 days.[2]

Intraoperative detection of GE injuries is clearly beneficial to the patient; yet, routine inspection for unsuspected injury is not a current component of standard foregut surgery. We have developed a gastric insufflation technique to facilitate intraoperative detection of such injuries. GIT is a simple, reproducible and low-cost technique for the detection of GE injury during LNF. The technique requires little modification of the common operation and few additional instruments. By routinely applying GIT, the surgeon can be better assured of the integrity of the GE junction with minimal delay and with little risk to the patient.

In our clinical practice, GIT is applied after the stomach and esophagus have been completely mobilized and just before fundoplication. Prior to introducing the bougie, the distal stomach is occluded with a laparoscopic, non-crushing bowel clamp, and the stomach is insufflated to maximal volume. Insufflation of the stomach can be greatly facilitated by attaching a pressure ball with a one-way valve (the type routinely found on sphygmomanometers or pressure bags) to the suction port of the nasogastric tube. The blue "sumping" port is clamped during insufflation. A manometer is not necessary once the surgeon is comfortable assessing maximal gastric dilatation. The patient is then placed in Trendelenberg position and irrigation is placed in the upper quadrant of the abdomen. Air bubbling signifies a break in the GE luminal integrity and requires further investigation and repair. The NGT should then be partially withdrawn to the esophagus and the proximal stomach occluded while the insufflation is repeated. The bougie is then advanced under direct visualization while appropriately manipulating the stomach.[2] If there is a question of occult GE injury after bougie placement, GIT can be performed after the fundoplication is completed. It should not be routinely necessary to perform GIT more than once, and it is expected that this will add three to five minutes to the total procedure time.

Although GIT appears to be a useful technique, there are several limitations to using an animal model to evaluate the question of its utility in humans. The porcine esophagus is much more pliable and muscular than that found in humans. Indeed, despite multiple attempts at angulating the GE junction, we were unable to perforate the porcine esophagus with either a nasogastric tube or 40F bougie. This appears to be because the porcine esophagus has a more developed muscular lining. Conversely, it has been demonstrated that the human esophagus can be easily perforated with an improperly placed bougie or operative dissection. This suggests that GIT may be even more sensitive in humans than in the animal model. The less muscular human esophagus might be more likely to leak air bubbles when submerged.

Our results suggest that it is more difficult than expected to identify small esophageal injuries with pyloric occlusion alone. However, proximal stomach occlusion routinely detects esophageal and GE junction injuries. While it is intuitive that clamping of the distal stomach and insufflation will identify meaningful breaks in the GE wall, we found that pyloric occlusion alone is not a suf-

ficient reassurance to GE integrity. Much higher volumes of air and many more manipulations of the stomach were required to demonstrate injuries when the pylorus alone was occluded. Indeed, the technique of proximal stomach occlusion was adapted from our clinical practice in which the distal stomach alone is occluded. It was added because we were dissatisfied with our ability to detect esophageal injuries in the pig model using pyloric occlusion alone. Proximal stomach occlusion and insufflation appears to effectively detect esophageal injuries of likely clinical importance (size range >2.5 mm). Pyloric occlusion and insufflation effectively evaluates the stomach for injury (size >2.5 mm) but, as noted, may miss esophageal defects. When combined, these two components of GIT provide a useful method for detecting GE injury after LNF.

Damage to the stomach and esophagus during Nissen fundoplication is associated with high morbidity and mortality when there is a delay in detection. The technique of gastric insufflation after LNF effectively evaluates the integrity of the GE wall and should allow better intraoperative detection of injuries. Gastric insufflation technique appears to be a useful adjunct to laparoscopic foregut surgery.

References:

1. Perdikis G, Hinder RA, Lund RJ, Raiser F, Katada N. Laparoscopic Nissen fundoplication: Where do we stand? *Surg Lap Endosc.* 1997;7(1):17-21.

2. Schauer PR, Meyers WC, Eubanks S, et al. Mechanisms of gastric and esophageal perforations during laparoscopic Nissen fundoplication. *Ann Surg.* 1996;223(1):43-52.

3. Lowham AS, Filipi CJ, Hinder RA, et al. Mechanisms and avoidance of esophageal perforations by anesthesia personnel during laparoscopic Nissen fundoplication. *Surg Endosc.* 1996;10:979-982.

4. Watson DI, Jamieson GG, Baigrie RJ, et al. Laparoscopic surgery for gastro-esophageal reflux: beyond the learning curve. *Brit J Surg.* 1996;83:1284-1287.

5. Collet D, Cadiere GB. Conversions and complications of laparoscopic treatment of gastroesophageal reflux disease. *Am J Surg.* 1995;169:622-626.

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